BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF METROPOLITAN DISTRICT COMMISSION BEACHES MASSACHUSETTS

PART D

NANTASKET BEACH

JUNE 1, 1949

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASSACHUSETTS

NANTASKET BEACH

TABLE OF CONTENTS

Paragraph No.	Subject	Page No.
	Introductory	iii
	Syllabus	iv

PART I - GENERAL

1.	Authority	1
3.	Purpose	2
4.	Prosecution of the Study	2
5.	Preparation of Reports	2

PART II - DESCRIPTION

6.	Location	3
7.	General Description	3

PART III - GEOLOGY

11.	Classification of Beach	5
12.	Bed Rock	5
13.	Surficial Deposits	5
14.	Geologic History	6

PART IV - FACTORS AFFECTING SHORE PROCESSES

15.	Composition of Beach	8
17.	Borings	12
18.	Probings	13
19.	Samples	13
20.	Wind	13
21.	Tides	14
22.	Storms and Their Effects	14

PART V - CHANGES IN BEACH AND OFFSHORE AREAS

28.	Changes in Shore Lines	21
29.	Profiles	22
30.	Offshore Depth Changes	23
31.	Littoral Drift	26

PART VI - EXISTING PROTECTIVE STRUCTURES

32.	Protective Structures for Bathhouse, Hotel and Pavilions	30
33.	Protective Structures for Parking Areas	33

PART VII - PLANS OF PROTECTION

34.	Analysis of Principal Features of Problem	37
37.	Plan of Improvement	38

PART VIII - ECONOMIC ANALYSIS

Paragraph No. Subject Page No.

39. Cost.................................... 40
40. Benefits................................ 40
41. Allocation of Costs..................... 42
42. Justification of Project................ 42

PART IX - DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

43. Co-ordination With Other Agencies.......... 43
44. Discussion................................. 43
49. Conclusions................................ 46
50. Recommendations............................ 47

PLATES

Plate No. Subject

1 Location of Metropolitan District Beaches, Massachusetts

2 Wind and Swell Diagrams, Hurricanes and Prevailing Winds

D-1 Existing Structures

D-2 Shore Line and Offshore Depth Changes

FIGURES

Figure No. Subject

D-1 Geological Development

D-2 Beach Conditions

D-3 Beach Conditions

NOT FOR PUBLIC RELEASE

BEACH EROSION CONTROL REPORT ON COOPERATIVE STUDY OF METROPOLITAN DISTRICT COMMISSION BEACHES, BOSTON, MASSACHUSETTS

INTRODUCTORY

The cooperative study of Metropolitan District Commission Beaches in Metropolitan Boston, Massachusetts, comprises studies of five beaches, one of which (Winthrop Beach) has previously been reported on to Congress. These beaches are essentially independent of each other, in so far as the scope of the study is concerned. The cooperating agency stated its objective in the prosecution of the study to be the determination of the best method of preventing further erosion, stabilizing, and improving the beaches, and protecting the sea-walls. Report on the remaining beaches is made in four parts, as follows:

A. Lynn-Nahant Beach
B. Revere Beach
C. Quincy Shore Beach
D. Nantasket Beach

SYLLABUS - NANTASKET BEACH

The Division Engineer finds that Nantasket Beach is relatively stable, that the sea-walls afford adequate protection to the area, that serious storm damage is not experienced in the area, and that although the beach is otherwise suitable for recreational use, the stones deposited on the backshore create conditions which now prejudice such use. The stones are the result of the reworking of existing beach materials, and their occurrence cannot be prevented. As the best method of achieving the desired objective, namely, the improvement of the beach, the Division Engineer recommends the establishment by local interests of a continuing maintenance program under which the stone deposits will be buried or removed, as conditions warrant.

CORPS OF ENGINEERS, U. S. ARMY
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION
BOSTON, MASS.

June 1, 1949

SUBJECT: Beach Erosion Control Report on Cooperative Study of Metropolitan District Commission Beaches, Boston, Massachusetts; Part D - Nantasket Beach.

TO: The Chief of Engineers
Department of the Army
Washington 25, D. C.

I. GENERAL

1. Authority. - A formal application from the Metropolitan District Commission of the Commonwealth of Massachusetts, dated August 9, 1945, for a cooperative study of beach problems within the Metropolitan District in the vicinity of Boston, Massachusetts, including Lynn-Nahant Beach, Revere Beach, Winthrop Beach, Quincy Shore Beach and Nantasket Beach, and providing for prosecution jointly by the Metropolitan District Commission and the United States was approved by the Chief of Engineers, United States Army, October 2, 1945, in accordance with the authority conferred by the provisions of Section 2 of the River and Harbor Act approved July 3, 1930 and Public Law 166, 79th Congress, approved July 31, 1945.

2. At the request of the Metropolitan District Commission, the study of Winthrop Beach was given priority over the study of other beaches to allow a separate report to be made on Winthrop prior to completion of the entire study. A report on "Beach Erosion Control Study, Winthrop Beach, Mass." was made by the Beach Erosion Board and submitted to Congress December 9, 1948, and is published in House Document No. 764, 80th Congress, 2nd Session.

3. Purpose. - The purpose of the investigation of the general study of Metropolitan District Beaches is to determine the best method of preventing further erosion, stabilizing and improving beaches, and protecting the sea-walls.

4. Prosecution of the Study. - The Commonwealth of Massachusetts, through the Metropolitan District Commission, contributed one-half the cost of the study. The field work and collection of basic data for the study were carried out by the District Engineer, Boston, Massachusetts, with the exception of economic data which was collected by the cooperating agency. A geological study of the five beaches, except the mainland section of the Lynn-Nahant Beach was prepared by the United States Department of the Interior, Geological Survey, under a cooperative geological project of the Massachusetts Department of Public Works. The report on Winthrop Beach was prepared by the Beach Erosion Board. The report on other beaches included in the study has been prepared by the Division Engineer, New England Division.

5. Preparation of Reports. - The five beaches comprising the study, in so far as their physical location and the scope of the study are concerned, are independent shore units which may properly be treated as separate beaches. A separate report has been prepared on Winthrop Beach. The report on the remaining beaches has been divided into four parts, as follows:

Part A - Lynn-Nahant Beach
Part B - Revere Beach
Part C - Quincy Shore Beach
Part D - Nantasket Beach

Each of the four parts is issued as a complete report for the subject beach, and contains general paragraphs numbered 1 to 5, inclusive, and Plates 1 and 2, which are common to all four parts.

II. DESCRIPTION

6. Location. - Nantasket Beach is located in the Town of Hull, Plymouth County, Massachusetts, about 4 miles southeast of the main entrance to Boston Harbor and 12 miles southeast of the City of Boston. The study area comprises the southerly end of the beach. (See Plate 1, U. S. Coast and Geodetic Survey Chart No. 246 and U. S. Geological Survey Nantasket Quadrangle.)

7. General Description. - Nantasket Beach is a complex tombolo uniting to the mainland several former drumlin islands. The study area is at the mainland base of the 3-1/2-mile section connecting Atlantic Hill with Great Hill, and consists of approximately 1 mile of beach exposed to the open Atlantic Ocean. This section of the tombolo has been developed principally as an amusement area and contains a public reservation, bath houses, hotels, restaurants and cafes, dance halls, amusement park rides and games, and similar enterprises associated with such areas. Areas behind the amusement center and on either side of it are developed for summer and winter residences, with the winter residences comprising a very small part of the development.

8. The Metropolitan District Commission reservation at Nantasket consists of the following: a wide beach, a sea-wall, a highway, and a public area generally 125-150 feet wide, containing parking grounds, pavilions, a hotel, a bathhouse, and sanitary buildings. The beach is wide and flat composed of hard-packed sand in foreshore and offshore areas, and soft sand and stones in backshore areas. The shore is constantly exposed to surf action.

9. Nantasket Beach is the result of a complex process of erosion and island tying that has resulted in the loss of five islands seaward of the present beach and the partial loss of other former islands which

are now hills on the peninsula. During this process, many different combinations of islands and connecting tombolos were effected until the present system was established. Since that time, the seaward face of the tombolo has prograded.

10. The peninsula is traversed its entire length by paved roads which constitute the southerly end of the State circumferential highway around Metropolitan Boston. The beach is also connected by an express highway to the main route to Boston. Public transportation is provided by a bus system from Quincy, Mass., which connects with several transportation systems serving the Metropolitan Area. The bus fare from Quincy is sixty cents a round trip. The minimum fare from Boston to Quincy is twenty cents. During the summer, there is direct steamboat service between the beach and the center of Boston, the beach terminal being on the Weir River side of the tombolo in about the center of the study area. The boat fare is one dollar for adults and seventy cents for children. Free public parking is provided in two large areas located between the highway and beach and adjacent to the bathhouse, pavilion and hotel area. Other limited parking facilities are provided along the highway. Public walks and promenades are provided in front of the parking areas and through the porches of the hotel, pavilion and bathhouse. The principal bathhouse in the area is operated by the Metropolitan District, and provides facilities for 5000 bathers. Private bathhouses provide facilities for 2000 to 3000 bathers. The daily attendance at Nantasket Beach during the summer is from 15,000 to 20,000 people. The average Sunday attendance is 150,000 people. Peak attendance on holidays is 175,000 to 200,000 people.

III. GEOLOGY

11. Classification of Beach. - Nantasket Beach extends from Atlantic Hill at the southeast and to point Allerton on the northwest and a distance of approximately $3\frac{1}{2}$ miles, (See Figure D-1). It varies in width from about 500 feet to approximately one-half mile. In the growth of Nantasket Beach several drumlin (glacial hill) islands were tied by beaches to the mainland at Atlantic Hill. Such a feature is called by many authorities a complex tombolo.

12. Bed Rock. - Bed rock crops out at Atlantic Hill and Hull. However, only an insignificant part of the material in Nantasket Beach was derived directly from bed rock, and at present, bed rock is of no importance as a source of material.

13. Surficial Deposits. - a. Till. - Point Allerton, Allerton Hill, Strawberry Hill, Whitehead, and Sagamore Head are drumlins (Figure D-1). They are composed of till (boulder clay, "hard pan"), a compact, unstratified, unsorted, surficial deposit containing angular and subangular fragments varying in size from clay to boulders, and all of them have been eroded considerably by waves and currents. After an examination of the ancient beach ridges of Nantasket Beach, the size and alignment of the marine cliffs cut in the drumlins, and the offshore profiles, Johnson and Reed*concluded that five drumlins were once located east of Nantasket Beach, but have been completely destroyed (Figure D-1). All of these drumlins had been deposited by the continental glacier which disappeared from the Boston area approximately 30,000 years ago. Waves and currents have

---

* D. W. Johnson and W. G. Reed, Jr., The Form of Nantasket Beach, Journal of Geology, Vol. XVIII, p.p. 162-189, 1910.

deposited the clay and silt sizes of the eroded and destroyed drumlins in Boston Harbor and Massachusetts Bay and have used the larger sizes in the construction of Nantasket Beach. Probably more than 90% of the material in Nantasket Beach was derived from these drumlins.

b. Strawberry Hill, Sagamore Head and Whitehead are now protected from marine erosion by the beaches which have prograded in front of them; Point Allerton and Allerton Hill are protected in most places by sea-walls. No material, therefore, is now being added to Nantasket Beach from these drumlins, nor does it seem likely that any material is now being added from the sites of the destroyed drumlins.

c. Outwash Sand and Gravel and Clay. - Outwash sand and gravel and blue clay are common in the Greater Boston area, but there are no known occurrences of such deposits in the Nantasket area. Even if they are present, they are not now important sources of beach material, nor have they been important in the past.

d. Summary. - An analysis of all the factors indicates that little material is now being added to Nantasket Beach.

14. Geologic History. - a. Till is the oldest surficial deposit in the area, although it is much younger than the bed rock on which it rests. Sea level stood at approximately its present position shortly after the deposition of the till and the recession of the ice. During this period, Strawberry Hill and other drumlins were islands. Following a short interval at this stand, sea level dropped slowly to a point scores of feet lower than the present position and at this time the drumlins were connected with the mainland. After a period of unknown length, the sea rose from this low level, the shore line moved westward, and the drumlins again became islands. Those east of the present Nantasket Beach were eroded and a series of connecting beaches were formed. Later, when the sea stood at or near its present position, the remaining drumlins were

cliffed and the western side of Nantasket Beach was formed. More material was added to this beach than was removed, and it prograded eastward until it reached its present position (Figure D-1).

b. From the geological point of view, Nantasket Beach has probably now reached its greatest possible size. In the future, if man does not interfere, it will slowly retrograde and become smaller because little or no material will be added to it.

IV. FACTORS AFFECTING SHORE PROCESSES

15. Composition of Beach. - In the vicinity of Atlantic Hill, Profiles 1 - 3, there are ledge outcrops along the shore. The beach is stony, containing many boulders and some sand deposits. Along the tombolo, northwest of Atlantic Hill, Profiles 4 - 14, the backshore is sandy with heavy deposits of stone covering the sand. Near the southeast end of the beach, the stones form a ridge in front of the parking area. The foreshore of the tombolo is hard-packed sand. The following notes indicate the composition of the beach on June 21,1946.

"a. Profiles 1 and 2. - (1) Profiles 1 and 2 radiate from a large ledge outcropping about 100 feet seaward of the coastal cliff. This cliff is ledge with a topsoil cover which generally supports a heavy growth of grass. The ledge outcrop is surrounded by water at times of extreme high tide. A ridge of shingle extends from the coastal cliff to the ledge, and there is a deposit of loose, medium sand on the seaward face of the ridge.

(2) Between Profiles 2 and 3, the foreshore area is stony containing a large number of boulders. At mid tide elevation, the beach becomes sandy while at high water level there is heavy deposit of shingle. Above the shingle, the coastal cliff rises abruptly and supports a grass cover.

b. Profile 3 Area (Fig. D-2). - The inshore end of Profile 3 is a ledge outcrop in front of the main coastal cliff. The beach fronting the ledge is hard-packed sand with a very flat slope.

c. Profile 4 Area (Fig. D-2). - (1) The beach is hard-packed sand and is very flat to a point about 30 feet in front of the high water mark. From this point, the beach assumes a slope of about 1 on 10 for a width of 10 feet. In this area, it is hard-packed sand with a considerable amount of small pebbles. Landward of this slope, there is a 10-foot strip of soft, fine sand. From the sand strip, a pile of stone, consisting of shingle and cobbles, slopes up to within 12 inches of the top of a concrete wall along the parking area. Ripples are impressed in the hard sand in the foreshore area.

(2) Maintenance men stated that when they first worked in this area, about twenty (20) years ago, there was no stone in the backshore area, but it was all sand. They also stated that the stone between Profiles 6 and 12 had been leveled off with bulldozers and scrapers and that sand had been pushed over the stones, burying them. This burying of the stones has been done annually. However, the stones south of Profile 6 have not been disturbed.

d. Profile 5 Area. - The beach is similar to that at preceding Profile 4, except that the belt of stones piled against the wall is much narrower in width, being about 10 feet wide while the soft sand belt becomes 20 to 25 feet wide. The hard-packed sand in front of the soft sand contains a regular series of ridges and valleys parallel to the profile.

e. Profiles 6 - 8 Area (Fig. D-2). - (1) Starting at a point about 200 feet north of Profile 6, scraper tracks clearly indicate the area in which stones have been buried. From this point northward to Profile 12, all beach elevations in backshore areas, except under pavilions, are artificial. The beach in front of the buried stone is the same as described for previous profiles, consisting of hard-packed, firm sand with a flat foreshore area and a slope to the backshore area.

(2) The beach under the overhanging section of the Tivoli pavilion is soft sand.

(3) Commencing with the hotel and extending northward, the stones in the backshore area have not been buried, but only levelled off. They are about 3 - 4 inches higher than the 10-foot wide belt of soft sand which lies in front of them.

f. Profile 9 Area (Fig. D-3). - At Profile 9, the foreshore area is flat, firm, hard-packed sand. The slope to the backshore area has become 20 feet wide and the soft sand area about 5 feet wide. Stones cover the backshore area between the soft sand and the wall.

g. Profile 10 Area (Fig. D-3). - The foreshore area is a flat beach of hard-packed sand. The foreshore slope is hard-packed sand with small cusps of small stones appearing on it. Behind this slope, there is a narrow berm of hard sand, and behind the berm, there is loose sand and stone. The loose sand rises with an abrupt six-inch scarp above the hard sand berm. There is more sand in the backshore area than at previous profiles. The beach elevation is about 2-1/2 to 3 feet below the top of the wall at the first steps north of the bathhouse.

h. Profile 11 Area. - The foreshore area is about the same as at previous profiles. The cusps on the hard sand foreshore slope are more pronounced, denser, and larger. Between Profiles 11 and 12, the backshore area is very sandy with heavy deposits of stones against the wall. The leveling of stone piles in backshore area by power equipment was stopped near Profile 11.

i. Profile 12 Area. - Only traces of the stone cusps appear on the foreshore slope. Stone piles against wall in backshore area have assumed a definite cuspate formation. The beach in the backshore area is about 50% sand.

j. Profile 13 Area (Fig. D-3). - (1) The last pile of stone against the wall lies against the south face of the first bastion near Profile 13. The hard-packed sand beach extends to within 25 feet of the sea-wall.

(2) In front of the bastion, the beach slopes to within 6 - 12 inches of the top of the toe wall around the bastion. This beach is hard-packed sand with very few pebbles in it. Ripples are impressed in the sand in foreshore areas.

(3) There is a flat berm of hard sand between the first and second bastion, the seaward edge of which is in line with the face of the first bastion and the landward edge is in line with the face of the second bastion. Behind this berm, there is a soft sand area extending to the wall.

(4) At the first bastion, the beach elevation is 6 inches below the top of the wall on the south side and 12 inches below the top of the toe wall on the north side.

k. Profile 14 Area (Fig. D-3). - (1) The beach is hard-packed sand to within 4 feet of the sea-wall.

(2) The second bastion wall is undermined for a depth of 6 inches, extending back to a wood cut-off wall. The beach is 6 inches lower on the north side of the bastion wall than it is on the south side.

l. End of sea-wall. - The beach elevation is 6 inches lower on the north side of the third bastion than on the south side. This lower elevation exists along the base of the main wall to its end. The remains of a destroyed wall lies in front of the sea-wall north of the third bastion.

m. North of the Sea-wall. - The coastal cliff sets about 30 feet behind the line of the sea-wall and is protected with a blanket of riprap whose stones average 3 - 4 cubic yards in volume. A concrete wall connects the riprap to the main sea-wall. The foreshore beach is hard-packed sand and is flat to a point within 60 feet of the riprap, where the beach rises on a slope of 1 on 6 to a point within about 30 feet of the riprap. Behind this slope, the backshore beach of soft sand to within 10 feet of the riprap has a slope of 1 on 10. The beach immediately in front of the riprap is composed of small stones."

16. An inspection of the beach was made after two northeast storms. The first inspection was made on December 3, 1945 after a very severe three-day storm. The second inspection was made on March 4, 1947 after a severe one-day storm. The general characteristics of the beach at these two inspections were very nearly the same. Stone deposits were much more dense at these times than they were in June 1946, but generally occurred in the same location. There were minor changes in beach elevations between the summer and winter inspections, but the only major variation occurred at the north end of the reservation sea-wall in the vicinity of the three bastions. Here beach elevations were as much as two feet lower after the storms than they were in the summer of 1946. In December of 1945 there was sand at the base of the north end of the wall, while in March of 1947 there were stone deposits. The beach north of the wall did not appear to change in elevation.

17. Borings. - Borings were taken along the centerline of road when it was reconstructed in 1932. These borings indicated that beach sand and stone lay below strata of gravel. The gravel strata included existing roadbed material and generally had a total depth of 0.6 to 1

foot. The beach sand and stone were generally found at elevation 16 above mean low water. The borings generally extended only one to two feet into the sand.

18. Probings. - Hand probings were taken along the beach, 300 feet seaward of the base line, on June 20,1946 at locations indicated on Plate D-1. Between Profiles 4 and 14, the material was sand overlying gravel. The penetration through sand varied from 1.5 to 2.5 feet. Penetration through the fine gravel varied from 0.1 to 0.7 feet.

19. Samples. - Samples of materials were taken at about mean tide elevation on June 13,1946 at locations indicated on Plate D-1. The samples were obtained on Profiles 5, 7, and 14. Analysis of the samples proved the materials to be identical at all three profiles. The median diameter of the material was 0.2 millimeters.

20. Wind. - A wind diagram compiled from observations of the U.S. Weather Bureau at Boston, Massachusetts, 1927-1937, and the yearly cumulative average ocean winds compiled from records of the U. S. Navy Hydrographic Office for the 5-degree squares nearest Nantasket Beach and other Metropolitan District Beaches are shown on Plate 2. An examination of these two diagrams indicates that, of the winds which blow over significant fetches of ocean before reaching the area, those from the northeast quadrant are prevailing and predominant. Nantasket Beach is exposed to the open ocean without any protection of headlands or islands. Its principal axis is northwest to southeast, and, therefore, is subject to the direct attack of the dominant and prevailing northeast winds which act on the coastline. All winds from the north, northeast, east, and southeast quadrants may act upon the shore with their full intensity.

21. Tides. - The mean range of tide at Nantasket Beach computed from the accepted value at Boston, Massachusetts, by application of a factor determined by the U. S. Coast and Geodetic Survey is 8.9 feet. The heights of extreme tides have not been recorded at Nantasket but those observed in Boston Harbor provide an excellent indication of the magnitude of fluctuations from the mean. At Boston Harbor the predicted spring tides range up to 12.0 feet, actual heights of extreme tides having been recorded up to 15.0 feet above mean low water.

22. Storms and Their Effects. - a. Hurricanes. - The paths of all hurricanes (defined as those with a central pressure of 29.0 inches or lower, and winds near the center. of more than 60 miles per hour in some points in the path) which have struck within a 150-mile radius of Nantasket Beach between the years 1874 and 1944 have been extracted from the book, "Hurricanes," by Ivan R. Tannehill and various other sources and plotted on Plate 2. An examination of this plate shows that between 1874 and 1945, a period of 71 years, 32 tropical storms of hurricane intensity have passed within a 150-mile radius of the beach.

b. Gales. - A summary of the record of winds of gale force or greater, compiled from records of the U. S. Weather Bureau at Boston, Massachusetts, covering the 75-year period 1870 to 1945, inclusive, is given in the following table:

DIRECTION OF GALES

1870-1945 (incl.)

Direction	Number of Gales	Percent of Total Gales
North	3	2
Northeast	80	50
East	9	6
Southeast	14	9
South	12	7
Southwest	15	9
West	13	8
Northwest	14	9
	160	100

The following table, based upon the gale record summarized above, indicates the number of days that gales from various directions may be expected during a 100-year period.

GALE FREQUENCY BY DIRECTION

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	TOTAL
Number of days observed 1870 to January 1946	4	131	9	15	12	20	16	18	225
Frequency in days per 100 years	5	175	12	20	16	27	21	24	300

During a 100-year period 175 gales, comprising 58 percent of all gales, may be expected from the northeast. Only 32 gales (11 percent of all gales) are to be expected from both the east and southeast.

c. Effect. - Storm damage along Nantasket Beach results from the action of wind-driven waves and their induced currents, and its severity is directly dependent upon the velocity and direction of the wind and the tidal stage during the storms. The configuration of the beach is such that it is acted on only by waves originating from the north through east to south directions. The winds from the northeast quadrant have great preponderance, in regard to both duration and velocity, over other winds producing waves that can act upon the shore.

The records of gales indicate that storms from the northeast have a much greater frequency and duration than storms from other quadrants. Since the axis of the open beach is northwest to southeast, the dominant northeast storms strike the beach without abatement in their fury and intensity and are the storms having the greatest effect upon the beach.

23. The offshore area of Nantasket is shoal, the 18-foot offshore depth curve being about 2,000 feet from the shore line. There is a constant surf action upon the beach. The protective structures within and adjacent to the study area are back of the high water line and are not generally subject to wave action under normal tidal and weather conditions. In the central part of the study area, pavilions are partially constructed on piles driven seaward of the protective structures. The recurrent storms attacking the beach have not wrought very much damage to the shore line structures. Records of specific storms and visual observations of storm damage indicate that the only important damage in recent years occurred at the northerly end of the study area where two sections of the sea-wall were washed out. This damage was the result of the impounding of water on top of the pervious fill behind the wall and not the result of wave action. Other reported damage has been minor, and comprised the washing of small amounts of beach materials and debris over the walls and adjacent roads and slight damage to the pavilion and hotel structures.

24. Storm damage as reported in recent years is as follows:

a. November 26-27, 1898. - High water damaged the underpinning of the Nantasket Hotel.

b. February 20, 1927. - (1) During a northeast storm, the five masted schooner "Nancy" was driven ashore at a point just beyond the present (1946) end of the sea-wall at the northerly limit of Metropolitan District Commission property. The vessel was sailing light. It came ashore almost perpendicular to the coast and was high upon the beach with the bowsprit projecting over the coast line. The storm was a moderate northeast storm having a wind with an average velocity of 35 m.p.h., and maximum velocity of 42 m.p.h. The storm began about 1:30 A.M. on February 19 and continued to about 6:00 P.M. on the 20th, slowly diminishing on the 21st. The storm was accompanied by a total accumulation of 11 inches of snow and sleet during the first two days. The highest recorded tide in Boston on the day the vessel came ashore was 11.8 feet, and recorded tides on this day ran about two feet higher than on the previous and succeeding days. Spring tides are commonly predicted as 12.0 feet for Boston Harbor, so the recorded storm tide was not excessively high. There is no record of other damage occurring at Nantasket during this storm and the general opinion is that other conditions, such as visibility and being off course, may have contributed to the cause of the wreck.

(2) The "Nancy" slowly swung its stern northward so that approximately 6 months later, on August 5, 1927, it lay at an angle of about 45° to the coast line. By February 18, 1938, it had swung parallel to the beach and had moved about 40 feet northward in making this swing. On April 22, 1940, it floated and started to move south along the beach. Local authorities broke the wreck up and removed it from the beach in the latter part of 1945. At this time the wreck was about 2500 feet south of its original position on the beach.

c. January 31, 1939. - During an easterly storm on January 31, 1939, a 175-foot section of the new sea-wall at the northerly end of the beach was displaced. The storm had been in progress all of the previous night and the wind and waves were striking perpendicular against the shore. The spray was cast fifty feet into the air as the waves struck the wall. The break in the wall occurred about 2 hours after high water, which was predicted to be 10 feet but was built up from 3 to 5 feet by the storm. The wall section did not break but slid forward as a unit between construction joints. This was due to hydraulic pressure of water ponded behind the wall. The section settled about one foot and its top tilted toward the sea.

d. November 12, 1947. - Heavy seas battered beach during northeast storms. Minor damage throughout Town of Hull.

e. December 26, 1947. - Business establishments along Metropolitan District Commission Reservations were damaged during northeast storm.

25. The following report of the effect of the northeast storm of April 20-22, 1940 was prepared by the District Engineer, Boston, Massachusetts, and was based upon field inspection.

"(1) Northeast storm accompanied by the highest tides since 1851.

(2) In the area in front of the hotel and pavilions there did not appear to be any evidence of damage or beach changes. At the north end of the Metropolitan District Commission Reservation a 175-foot section of the concrete sea-wall was tipped forward by the waves to an angle of 45-60 degrees from the horizontal. The initial

movement of this section occurred in storm of January 31, 1939. The failure of the wall was apparently due to the fact that this section of wall had not been backfilled before the storm came. The wall was broken at some of the construction joints, but it could be jacked back into place and repaired. The beach was disturbed to such an extent that the hull of the old 5-mast schooner "Nancy" was uncovered and floated 1/4 mile along the beach. This had been buried for years and man had never been able to move it. The storm washed stone and boulders up over the sea-wall smashing the bituminous paved road and parking area behind the wall and covering them with rocks. Debris was swept one block inland. The damage resulting from the storm in this area was estimated to be$2,500."

26. The following report on the storm of November 30, 1944 was prepared by a member of the staff of the Metropolitan District Commission.

"At about 1:00 P.M. on November 30, 1944, a 160-foot section of the extreme northerly end of the sea-wall north of the bathhouse was dislodged by hydraulic pressure and beach erosion. The hydraulic pressure was due to impounding of water washing over the wall. The beach, in places, was scoured below the bottom of the toe of the wall. The section that was dislodged included a large part of the most northerly bastion, and it is believed that the wall, steps and bastion moved instantaneously as a unit. The height of the predicted tide for this date was 11.5 feet which was in the range of the highest spring tides. The actual tidal height was several feet higher due to the storm wave."

27. The following report on the 3-day northeast storm of November 28-30, 1945 was prepared by the District Engineer, Boston, Massachusetts, and is based upon field inspection. This storm was 53 hours in duration, in which the wind attained a maximum velocity of 68 m.p.h. The storm came at a neap range of tides in which predicted tides at Boston, Massachusetts, were from 8.4 to 8.9 feet. The recorded tides in Boston were 9.1 to 12.5 feet, which approached and exceeded maximum normal tides. This storm caused extensive damage all along the coast.

"Roads along Nantasket Beach were washed over and covered with a moderate amount of sand and debris. Minor amounts of damage due to sea action occurred to benches, railings and steps at the pavilion and one large section of the pavilion roof was blown off. Wind damage also occurred to amusement structures."

V. CHANGES IN BEACH AND OFFSHORE AREAS

28. Changes in Shore Lines. - a. General. - Changes which have been effected along the shore line of Nantasket are indicated by the comparative mean high and low water lines shown on Plate D-2. The shore lines for 1847, 1893, and 1944 were developed from original surveys by the U. S. Coast and Geodetic Survey. The 1946 lines were developed from a survey by the Corps of Engineers.

b. Movements of the Mean High Water Line. - The movements of the mean high water line have been slight, being generally less than 50 feet and never exceeding 100 feet during the period of record. Both accretion and erosion have taken place along the entire beach between Allerton Great Hill to Atlantic Hill, with accretion dominating between 1847 and 1944. Within the study area there was erosion between 1847 and 1893 resulting in a horizontal movement landward of the mean high water line from 20 to 60 feet. Between 1893 and 1944 the beach prograded and mean high water line moved seaward to approximately the position it occupied in 1847. The 1946 mean high water line is generally about 40 feet seaward of that of 1847, except between Profiles 2 and 3 where it was 80 feet seaward.

c. Movements of the Mean Low Water Line. - The movement of the mean low water line is shown for only two years, 1847 and 1893, for the entire length of Nantasket Beach. During this period erosion was effected along the entire length of beach, between Allerton Great Hill and Profile 14 (north of the Study Area). The horizontal movement of the mean low water line was generally 180 feet landward, varying between 150 and 300 feet. Within the study area, Profiles 14 to 1, there were both erosion and accretion, with accretion slightly dominating. Accretion averaging 50 feet in shore line movement was effected between

Profiles 14 and 8 and between Profiles 8 and 6, there was a landward movement in the shore line of 40 feet. Within the study area, the mean low water line remained stable from 1893 to 1946, except for a landward movement varying up to 160 feet between Profiles 12 and 10, and 100 feet between Profiles 6 and 3. Accretion between Profiles 2 and 1 resulted in a seaward movement varying up to 140 feet. The net result of changes at the mean low water line during the period of record, 1847 and 1946, has been accretion nearly balancing erosion. The 1946 mean low water line is seaward of the 1847 line between Profiles 14 and 12, 10 and 8, and 4 and 1, and is landward between Profiles 12 and 10 and Profiles 8 and 4.

d. Summary. - The movements of the shore lines indicate a relatively stable beach has existed since 1847. Slight accretion has been effected along the mean high water line and slight changes, alternately accretion and erosion has been the net effect along the mean low water line. The average movement of the high and low water line has been approximately 25 feet. The beach slope between mean high water is generally 1 on 46, which indicates that elevations have changed less than one foot during this period. The movement of the mean low water line has generally been about 40 feet. The average beach slope between mean low water and the 6-foot offshore depth curve is 1 on 72. This also indicates that beach elevations have changed less than one foot.

29. Profiles. - The profiles surveyed by the District Engineer were the first beach profiles taken at Nantasket Beach. Prior surveys of the beach are of such limited scope as to prohibit the development of comparative profiles. Construction drawings for the sea-walls at the southerly parking area and at the present public bathhouse show beach

elevations prior to wall construction. These elevations indicate that at Profiles 5, 6, 8, and 9 beach elevations at the wall have increased 2.5 to 3.0 feet, and 10 feet seaward of the wall have increased 1.5 to 2.0 feet.

30. Offshore Depth Changes. - a. General. - Changes which have taken place in offshore areas are indicated on Plate D-2 by the comparative 6, 12, and 18-foot depth curves. These curves are developed from the surveys used for the development of the shore lines discussed in Paragraph 28. The curves for the year 1946 extend only through the study area, Profiles 1 to 14, inclusive, while curves for other years extend along the entire beach from Allerton Great Hill to Atlantic Hill. The changes indicated by these curves reflect changes in elevation in a moderately flat area, the offshore slopes as determined from the profiles averaging 1 on 72 between mean low water and the 6-foot depth curve, and 1 on 93 between the 6 and 12-foot depth curves.

b. Changes at the 6-foot Depth Curve. - Between 1847 and 1893 the result along the 6-foot depth curve for the entire beach was accretion in the northerly part of the area (north of a point about 2500 feet north of Profile 14) and erosion in the southerly part of the area. In the accretion area the 6-foot curve moved seaward for distances varying up to 200 feet and in the erosion area moved landward for distances varying up to 100 feet. Between 1893 and 1944, the 6-foot curve moved both landward and seaward in the northern part of the area, with erosion and accretion nearly balancing, while in the southern part of the area continued erosion moved the 6-foot curve landward for distances varying up to 100 feet. The net result between 1847 and 1944 for the entire beach has been accretion in the northern part of the area and erosion in the southern part. Within the study area, Profiles 1 to 14, inclusive, the depth curve for 1946 indicates both erosion and accretion between 1944 and 1946, and erosion between 1847 and 1946, the curve for the latter year being generally between 100 and 180 feet landward of that of the earlier year.

c. Changes at the 12-foot Depth Curve. - Between 1847 and 1893 the net effect of the movements of the 12-foot depth curve were similar to those along the 6-foot curve. North of a point about 4,000 feet north of Profile 14, there was general accretion with the seaward movement of the curve varying up to 200 feet. However, there were areas in which the curve remained stabilized or moved landward. South of the above noted point, there were varied movements indicating both erosion and accretion during the period, but erosion dominated between Profiles 14 and 8 with the 1893 curve being generally from 100 to 140 feet landward of the 1847 curve. Accretion was the local result between Profiles 8 and 1. Between 1893 and 1944, the 12-foot depth curve morth of Profile 12 moved seaward for distances varying up to 180 feet. South of Profile 12, erosion moved the curve landward for distances varying up to 50 feet. The net effect between 1847 and 1944 has been accretion in the northern part of the area and varying amounts of erosion and accretion in the southern part of the area. The movements of the depth curves in the northern part have been approximately twice that of the curves in the southern part. The 1946 depth curve indicates that since 1847 there has been accretion between Profiles 14 and 12, erosion between Profiles 12 and 6, accretion between Profiles 6 and 2 and erosion in the vicinity of Profile 1. Movements of the depth curves between 1847 and 1946 have varied up to 150 feet but the average movement is about 50 feet. It is to be noted that while erosion has taken place between Profiles 2 and 1 since 1893, the 1944 curve indicates s shoal area forming about 500 feet seaward of the main 12-foot curve.

d. Changes at the 18-foot Depth Curve. - The movements of the 18-foot depth curves do not evidence any continuous process of erosion or accretion in specific areas, but show that the processes reverse themselves at different periods. Between 1847 and 1893 erosion dominated the area north of Profile 14, with the 18-foot depth curve moving distances varying up to 300 and 400 feet landward in erosion areas and varying up to 150 feet seaward in accretion areas. Between Profiles 14 and 1 accretion dominated the area, with the movement of the curve for 1893 averaging 200 to 300 feet seaward. Between Profiles 2 and 1, the 1893 curve indicates a shoal about 200 feet seaward of the main depth curve. Between 1893 and 1944, the processes of erosion and accretion were reversed in many areas. The net effect north of Profile 14 was accretion with the depth curve movements varying up to 250 feet and averaging 150 feet. The 1944 curve shows a number of new shoal areas seaward of the main depth curve, the shoals being from 300 to 1500 feet seaward of the curve. Between Profiles 14 and 1, there was generally erosion with the average landward movement of the depth curve being 100 feet. Between Profiles 2 and 1, however, the depth curve moved seaward to include the small shoal shown by the 1893 depth curve, and another small shoal is shown still further seaward. The net effect shown by the 18-foot depth curves for the total record period, 1847 to 1944, is generally erosion north of Profile 14 and accretion between Profiles 14 and 1. In the areas of greatest erosion the depth curve is about 200 feet landward of the original position and in the areas of greatest accretion it is from 150 to 500 feet seaward of its original position.

e. Summary. - The movements of the 6, 12 and 18-foot depth curves do not evidence any long term regime of erosion or accretion. The processes of accretion and erosion have been effected to varying degrees at all points along the three depth curves with the net results of all movements along the 6 and 12-foot curves being generally reversed in comparable sections of the 18-foot curve. The magnitude of the movements has been greater in the northern part of the offshore area as well as along the deeper contours. The magnitude of these movements reflects the movement of contours due to changes of elevation on flat slopes rather than movement due to the degree of intensity of erosion or accretion. The net effect of all movements may be summarized as indicating a relatively stable area.

31. Littoral Drift. - a. General. - The open location of Nantasket Beach is such that a north to south littoral drift might be anticipated under the influence of the dominant coast-affecting northeast winds and storms. There is little to be observed that substantiates the existence of such a drift.

b. Drift Indications of Shore Line and Offshore Changes. - The study of the shore line changes indicates that the beach between Allerton Great Hill and Atlantic Hill is relatively stable. Between 1847 and 1946 there was slight accretion along the entire high water line, with considerable accretion between Profiles 2 and 3. Field inspection shows the area between Profiles 2 and 3 to comprise a stone and shingle beach. Between 1847 and 1893, the low water line retrograded an average distance of 200 feet north of Profile 14, but south of this Profile there was both slight prograding and retrograding. Since 1893 the low water line has been relatively stable south of Profile 14, with areas of erosion and accretion nearly balancing. There has been accretion between Profiles 1 and 3, and field inspection shows this area to be stony and boulder strewn. The movements of the 6-foot depth curves for the years 1847, 1944, and 1946 show that accretion has been the net effect on the northerly part of the beach and erosion on the southerly part of the beach. The movements of the 12-foot depth curve show that there has been accretion in the northerly part of the area and both erosion and accretion in the southerly part of the area. The movement of the 18-foot depth curve shows erosion in the northerly part of the area with shoals forming seaward of the main depth curve, and accretion in the southerly part of the area. The movements of the shore lines and depth curves do not follow a pattern which would occur under a definite littoral drift from either north or south. It is to be noted that the high and low water lines at the base of Atlantic Hill, Profiles 1 to 3, show accretion and that field inspection shows a stony and shingle beach. If the accretion was effected under a north to south littoral drift the material would be sand from the long, sandy beach between Atlantic Hill and Great Hill. Field inspection also shows that a stone ridge forms in front of the sea-wall between Profiles 4 and 6.

c. Movement of Wreck. - In 1927 the Schooner, NANCY, was driven perpendicularly ashore at a point north of Profile 14. By 1938 it had swung parallel to the beach and moved about 40 feet northward. Various conditions, other than wave action, reduced the schooner to a hulk which was eventually buried by sand. A storm in 1940 uncovered the schooner and it started to move southerly along the beach. The hulk was finally removed in 1945, at which time it was about 2500 feet south of the initial point of its beaching. The size of the hulk was such that it would be moved great distances only under storm conditions. Its movement indicates, therefore, that during great storms a north to south drift existed along the section of beach traversed, the storms being the dominant northeasters. However, during other than storm periods, indications are that a south to north drift existed in the vicinity of the original beaching.

d. Sand Catchers. - There are no great projections on the beach to act as sand catchers. The north end of the sea-wall projects about twenty-five feet seaward of the riprap protecting the more northerly beach. There has been no accumulation of sand or other beach material noted against this wall. Instead, erosion of two feet in depth has been noted at two periods around this corner of the wall, with the beach rebuilding between the two observations. There are three bastions near the north end of the wall, the largest one projecting thirty-five feet seaward of the wall. It has been noted that the beach is generally lower on the north side than on the south side of these bastions. The same erosion has occurred at these bastions as at the north end of the wall, with a similar rebuilding of the beach. At the steps in front of the hotel and pavilions, beach elevations are higher on the north side than on the south side. The differences in beach elevations on the sides of steps and bastions do not indicate a continuous direction of littoral drift.

e. Geological History. - The modern Nantasket Beach assumed its present configuration only after a long series of shore line processes. Originally there were a number of drumlin islands in the area north of Atlantic Hill. The forces of erosion and accretion attacked these islands, wearing them away and used the materials to build spits to tie the islands together. In the development of Nantasket Beach, there were a number of different combinations of islands and connecting tombolos. The final development of the beach resulted in the loss of five of the drumlin islands and the partial erosion of others. The shore line was at the seaward base of the remaining islands. Since this development the shore line has prograded so as to be from 200 to 1000 feet seaward of the base of the remains of the islands that lie between Allerton Great Hill and Atlantic Hill. The development of Nantasket Beach does not suggest that it was built under the influence of any one dominant littoral drift.

f. Sources of Materials. - Nantasket Beach was built from materials eroded from the many drumlins which were in the area. The drumlins were composed of glacial till, a deposit containing unsorted fragments varying in size from clay to boulders. The silt and clay sizes were deposited in Boston Harbor and Massachusetts Bay and the remaining sizes were used for building Nantasket Beach. The bases of the remaining drumlins are protected from wave and current attack by beaches generally hundreds of feet wide or by protective structures. It does not appear that material is available either from the remaining drumlins or from the sites of the destroyed drumlins. There are, therefore, no great sources of materials for feeding the beach.

g. Summary. - The analysis of all factors affecting littoral drift along Nantasket Beach offers no conclusive evidence of the existence of littoral drift. There is no apparent source for obtaining drift material other than from the beach itself and there is no definite movement of materials along the beach. The stones which appear on the beach are in the beach materials and appear from the re-working of such material.

VI. EXISTING PROTECTIVE STRUCTURES
(Plate D-1)

32. Protective Structures for Bathhouse, Hotel and Pavilions. -

a. Original Construction. - (1) The first public house was erected in the area in 1826 and was followed by numerous inns, cafes and amusement centers which were erected so as to project over the high water line. All such structures are now removed, except the Nantasket Hotel, the Pavilion and the Rockland Cafe (also called the Clambake) which are now operated or supervised by the Metropolitan District Commission. These structures were originally erected about 1870 and are wood structures supported on wood posts. Porches of these buildings projected over the high water line and wood bulkheads limited the tidal flow under the main parts of the structures. The wood bulkheads have been replaced with concrete walls and bulkheads.

(2) About 1880, a steam railroad was constructed along the peninsula, crossing from the Weir River side at about Profile 10 to run northwesterly along the Atlantic shore line. The road was subject to wave wash and in 1882, a section of the tracks was destroyed by a shipwreck. Prior to 1900, heavy riprap, composed of 3-4 cubic foot stone, was placed along the ocean side of the roadbed to protect it. The riprap is still in place and in good condition for some distance immediately north of the Metropolitan District Commission Reservation. Within the limits of the reservation, the riprap is buried under fill placed behind the sea-walls. The tracks have been removed for the entire length of the beach.

b. Sea-Wall at Bathhouse. - The concrete sea-wall between Profiles 9 and 10 was constructed in 1916 when the area was used for amusement rides. The circular section of the wall was introduced in front of an existing merry-go-round. The amusement rides have been removed and replaced by the present state-operated bathhouse. The concrete wall is located about 45 feet seaward of a wood bulkhead which was constructed about 1900. The wall is a gravity-type wall having a curved face, a projecting coping and an integral toe below the wall proper. The top elevation of the wall is 19.59 feet above mean low water; the base elevation varied from 10.19 to 11.69 feet above mean low water; and the elevation of the bottom of the toe from 7.59 to 9.19 feet above mean low water. The wall is approximately 1425 feet long and is provided with steps at either end and either side of the circular section. The wall has not suffered any known damage. The backshore of the beach fronting the wall is stony with dense piles of stones against the wall. The foreshore of the beach is hard-packed sand. Beach elevations are approximately 15 feet above mean low water.

c. Sea-Wall at Rockland Cafe and Nantasket Pavilion. - The concrete sea-wall around the Rockland Cafe and the Nantasket Pavilion, in the Profile 8 to 9 area, was constructed in 1927. Prior to this time, the porches of these structures overhung the beach and extreme high tidal water and wave wash flowed under them. The flow of tidal water was limited by a wood bulkhead constructed in 1913 at about the main building lines. The top of the wall is approximately 19.5 feet above mean low water and the wall has a sloping face with a projecting coping. The concrete steps leading to the beach were constructed in 1928. The sea-wall is in good condition and has not suffered any damage. Under severe storm conditions, wave wash has swept over the wall creating minor damage in the pavilions and passing through the pavilions out the adjacent street. The beach immediately adjacent to the wall is stony, with stone piles building up to within 3 feet of the top of the wall during the winter. Adjacent to the foreshore area is a 10-foot belt of soft sand. The foreshore area is hard-packed sand.

d. Bulkhead at Nantasket Hotel. - The concrete bulkhead under the Nantasket Hotel, between Profiles 7 and 8, was constructed in 1920 to replace a wooden bulkhead constructed in 1913. The porch of the hotel projects 20 feet seaward of the bulkhead line. The bulkhead is in good condition with a top elevation of approximately 19.5 feet above mean low water and 2 to 3 feet above beach level. The hotel porch is supported by piles, and sloping fender piles are installed in front of the bearing piles to prevent floating objects damaging the piling and bulkhead during storm tides. The backshore area is stony with a belt of soft sand near the high water line. The foreshore area is hard-packed sand. There is no record of the bulkhead having been damaged.

e. Wall at Tivoli Pavilion. - The concrete wall from the hotel to the Tivoli Pavilion and under the pavilion and adjacent sanitary, between Profiles 6 and 7, was constructed in 1915. Between the hotel and the pavilion, the wall has a top elevation of 21.59 feet above mean low water. The wall under the pavilion has a top elevation of 20.61 feet above mean low water. There are a series of 2-1/2 feet by 5 feet openings along the top of the wall for which wooden shutters are provided, but since the shutters are not always kept in position, the effective height of the wall is reduced to 18.19 feet above mean low water. The base of the wall is at elevation 11.29 feet above mean low water and the bottom of an integral toe wall is at elevation 9.19. The face of the wall is vertical above elevation 17 and curved below that elevation. The bench at the base of the wall is about 16 feet above mean low water. A porch projects over the beach in front of most of the wall and is about 20 feet wide. The backshore area of the beach is stone and sand. The foreshore is hard-packed sand.

f. Effect of Walls. - The walls protecting the buildings along the shore line have withstood all storm attacks with only minor damage occurring thereto. High seas have washed under the overhanging porches to damage the supports of the porch. Damage has also been suffered by the buildings through wave wash and debris which has been thrown up onto the porches. The beach has built up in front of these walls.

33. Protective Structures for Parking Areas. - a. Sea-Wall at Southerly Parking Area (Figure D-2). - The sea-wall fronting the southerly parking area, between Profiles 4 and 6, was constructed in 1915 with the exception of 225 feet immediately adjacent to Profile 4, which was constructed in 1927. The wall was built to replace a wooden bulkhead and is a curved-face gravity-type wall having a projecting coping and an integral toe. The top of the wall is at elevation 18.19 above mean low water, the base is at elevation 11.69 above mean low water, and the bottom of the toe is at elevation 9.19 above mean low water. The wall has a top width of 1 foot and a base width of 3 feet 4 inches. The wall is in good condition and has been repaired where minor spalling has occurred. A ridge of stone builds up in front of this wall generally to within a foot of its top. When the wall was constructed, the beach was sandy and 3 to 4 feet below the top of the wall. The foreshore area of the beach is hard-packed sand. The wall has provided adequate protection for the parking area.

b. Sea-Wall at Northerly Parking Area (Figure D-3). - (1) The sea-wall fronting the northerly parking area, north of Profile 10, was built by Metropolitan District Commission field forces in sections as funds and labor were available. The first section was built about 1926 between the ramp near Profile 10 and the steps near Profile 11. Between 1927 and 1936, the wall was extended to the bastion at Profile 13. The bastion was built in 1936. The wall was extended to the next bastion in 1937 and to its present end in 1938, so that its present total length is approximately 2500 feet. The wall was constructed of unreinforced concrete, with a curved face, a projecting coping to return wave wash to the beach, and an integral toe below the main wall. It has a top width of 16 inches at elevation 19.59 feet above mean low water and a bottom width of 3.75 feet at elevation 10.59 feet above mean low water. The toe is 1.5 feet thick and extends 3 feet below the wall. The beach varies in elevation from 10 to 14 feet above mean low water at the base of the wall. Access to the beach is provided at various locations by steps set at right angles to the face of the wall. A ramp is provided near the southerly end. Three bastions are located at the northerly end, the largest bastion, at Profile 13, being designed as the foundation of a future sanitary building. Prior to construction of the wall, the area was protected with heavy riprap placed along the bed of a railroad which passed through the area and northerly along the beach. The riprap was generally 30 to 40 feet behind the face of the wall and was buried by fill placed behind the wall. The northerly end of the wall is tied to the riprap by a temporary concrete bulkhead and the riprap still protects the shore north of the sea-wall. Fill for the area behind the sea-wall was largely obtained from the beach, and it is reported that the beach rebuilt itself after the material was removed.

(2) The wall is in good condition. South of Profile 13 it has never suffered any major damage. At Profile 12 the upper part of the steps are cracked. North of Profile 13, the wall has been seriously damaged and two sections were demolished and rebuilt. There is at present some cracking of concrete, spalling of surfaces and undermining of bastions. In 1941, about 175 feet of wall was reconstructed

to replace a section which was tipped forward in the storm of January 31, 1939. This section was between the two bastions north of Profile 14. The new wall is of reinforced concrete and increased section. It has a top width of 1.5 feet, a bottom width of 4.25 feet and a toe width of 2 feet. In addition, it has a heel which projects 32.5 inches in back of the wall for a depth of 1.5 feet below elevation 10.19. In 1944, the extreme northwesterly end of the wall was rebuilt for a distance of approximately 160 feet including a part of the most northerly bastion. This work was required by the dislodgment of approximately 130 feet of wall in the storm of November 30, 1944. The pervious fill behind the wall, except at the northerly section where the failures occurred, has been sealed with bituminous pavement. Metropolitan District Commission engineers report that the sections of wall did not fail structurally but tilted and slid seaward as a unit under hydrostatic pressures created by wave wash impounded over the unsealed backfill. In the first failure, there was no erosion of the beach prior to the movement of the wall section. In the second failure, the beach was eroded below the bottom of toe. Records indicate that the 1940 storm eroded the beach for a vertical depth of approximately 4 feet.

(3) The sea-wall in front of the northerly parking area has protected the coast from serious erosion and damage. Heavy storms, however, have washed over the wall and caused minor flooding of adjacent areas and damage to structures beyond the parking area. It appears that the beach tends to build up in front of the wall but great changes in beach elevations are effected during storm periods. In December 1945, it was noted that toes of the northerly two bastions were exposed for heights of thirty inches, while in June 1946, they were exposed only for heights up to six inches. In March 1947 beach elevations were again like those of December 1945. It has also been noted that wave attack

on the face of the bastions and the adjacent backshore beach creates heavy scouring action on the northerly sides of the bastions. The beach fronting the wall is generally stony on the backshore and hard-packed sand on the foreshore. The backshore becomes sandy towards the northwesterly end of the wall.

VII. PLANS OF PROTECTION

34. Analysis of Principal Features of Problem. - The study of shore lines, geological history and littoral drift indicates that the beach is stable. The specific area of the beach to be considered in this study comprises the Metropolitan District Commission's Reservation which extends approximately one mile north from the mainland base of the tombolo and is one of the two principal recreational beaches in the Greater Boston area. This area is protected by a series of concrete sea-walls and bulkheads which are constructed along the entire backshore of the reservation and have not been damaged by direct wave action, the only damage experienced being due to improper drainage of backfill. Storm damage in the area has been slight, consisting of minor breaking of siding and similar parts of buildings and of minor washouts in roadways caused by wave wash and debris going over the top of the protective structures. The pavilions and porches built on piles in front of the sea-walls are never seriously damaged by storm action. There is a wide, flat beach in front of the sea-walls, about 75 feet wide at mean high water and 500 feet wide at mean low water. The beach was formerly a fine, sandy beach soft in the backshore area and firm, hard-packed in the foreshore area. During recent years stones have appeared on the surface in and above the upper tidal ranges, creating undesirable conditions for the recreational use of the beach. The Metropolitan District Commission has for some years buried these stones in the sands prior to the opening of the bathing season.

35. The cooperating agency's objective in this study is the determination of the best method of preventing further erosion, stabilizing and improving the beaches, and protecting the sea-walls.

36. Nantasket Beach has for many years been relatively stable. Where erosion has occurred, the beach has subsequently rebuilt itself. The sea-walls have withstood direct wave attack and adequately serve their purpose. The wall failures which occurred could have been avoided by providing proper drainage for wave wash, and future failures may be expected unless the unpaved portion of the northerly parking area is paved to seal the pervious fill and provide proper runoff for wave wash. The sealing of this fill does not constitute a beach problem. The only beach problem existing at Nantasket Beach is that created by the stones appearing on the beach.

37. Plan of Improvement. - Shore line processes subsequent to initial beach construction and man's activities in building protective works have long ago sealed off all the natural sources of materials for the continued building of Nantasket beach. Analysis of changes in shore lines and offshore depth curves, factors determining littoral drift, and data on changes in beach elevations indicates that the beach is relatively stable and there is no great evidence of materials moving along the beach. The absence of a source of material and of littoral drift precludes the consideration of sand catching structures to bury the stones. Since the stones are within the sizes of glacial till from which the beach was built and there is no source now available for beach building materials, the stones apparently are appearing through the reworking of existing beach materials. The erection of sea-walls, groins or similar structures will not arrest this process. The stones could be buried by an artificial sand deposit, but the building of an artificial beach is not required in this area for the protection of the upland or the increasing of recreational facilities.

The control of the stone deposits thus resolves itself into a local beach maintenance problem of removing or burying stones when and as they become objectionable.

38. The local control of the stones may be accomplished by various methods. Light deposits may be buried in existing sands. Heavier deposits of stone may be leveled off and sufficient artificial fill placed over the deposit to cover it. Stones may also be removed from the beach and replaced with an equal volume of artificial fill to maintain the stability of the beach. The particular method to be employed will depend upon the beach conditions and the decision of the local authorities at the time the maintenance work is accomplished.

VIII. ECONOMIC ANALYSIS

39. Cost. - An estimate of the cost of maintaining the beach is not made as such work is dependent upon changing beach conditions and the method of doing the work elected by the cooperating agency.

40. Benefits. - Nantasket Beach is the only beach south of Boston with State operated and large privately operated bathing facilities and an amusement park. Nantasket Beach has thus become the most popular beach south of Boston, attracting people with all types of recreational desires. The daily attendance varies between 15,000 and 20,000 people, while Sunday and holiday attendance varies between 150,000 and 200,000 people. The present beach development represents an important investment of both public and private funds. The public investment has an estimated value in State and Town property as follows:

a.	Land	$ 400,000
b.	Sea-wall- bulkheads.	500,000
c.	Pavilions.	45,000
d.	Buildings.	1,000,000
e.	Roads.	110,000
	TOTAL.	$2,055,000

The private investment as represented by assessed valuations of the area lying behind the Metropolitan District Commission Reservation and bounded by Nantasket Avenue, George Washington Boulevard and Rockland House Road is as follows:

	Assessed Valuation
Frontal Property (adjacent to shore road and beach).	$ 503,900
Marginal Property.	573,520
Total Assessed Valuation	$1,077,420

The present sales value of private property is 1.33 times the assessed valuation. The 1948 tax return on the assessed valuation is

Frontal Property.	$ 21,700
Marginal Property	24,700
Total Tax Return	$ 46,400

If the stone deposits were allowed to become objectionable on the beach, great losses would result to both public and private investments. The state reservation would become undesirable for bathing and other beach activities, thereby decreasing in value. Beach patrons who principally desired swimming or other beach activity would be forced to look for other areas in which to pursue their activities. In many cases this recreation would be found at more distant and privately operated beaches, with the result that a part of the public would re-buy through added transportation and entrance charges, the privileges and facilities already purchased in the development of the State Reservation. The revenue to the state derived from bathhouse charges and concession payments for the state owned waterfront hotel and pavilions would be less, due to the smaller attendance at the beach. Private interest would also suffer as the profits on its investments in the amusement industry would diminish. Tax income to Governmental bodies would be reduced through lower income taxes and real estate valuations. Employment would also suffer in the local amusement industry. The benefits to accrue through the control of stone deposits on the beach are thus the benefits to be derived through the maintenance of a good asset. The principal benefactor will be the public, who, through the cooperating agency, developed the beach for its own recreation. A monetary value cannot be properly assigned to such a benefit. The secondary benefactors would be the private amusement operators and the

Governmental taxing authorities through the maintenance of their profits and tax income.

41. Allocation of Costs. - a. Federal Interest. - Federal interest is not involved at Nantasket Beach as the United States is not a land owner nor under existing law does it participate in maintenance programs at beaches.

b. Non-Federal Interest. - The Commonwealth of Massachusetts owns as a public reservation, the shore, the sea-walls, the lands immediately adjacent to the sea-walls, the buildings on these lands, and the adjacent highway. Land behind the reservation is privately owned. The Metropolitan District Commission maintains the beach and employs regular personnel for that purpose. Future maintenance remains the responsibility of local authorities.

42. Justification of Project. - Nantasket Beach is one of the two largest beach resorts adjacent to Metropolitan Boston. It is the only major beach south of Boston at which large public facilities are maintained by either public or private funds. The development of the area as a public reservation has involved large expenditures of public funds. The maintenance of the beach in a proper condition for recreational purposes is in the best interest of the public. Benefits derived from private investments in the amusement industry in the area will generally benefit the public through the maintenance of tax returns on profits and real estate, the maintenance of rental income of concessions in state-owned buildings and in maintenance of employment levels in the area.

IX. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

43. Co-ordination with Other Agencies. - The results of the study of Nantasket Beach and the recommended program of maintenance work as developed from this study have been discussed with the engineering representatives of the cooperating agency. The engineering representatives concurred in the recommended maintenance program.

44. Discussion. - After a complex process of erosion of drumlin islands and the formation of complex tombolos, Nantasket Beach assumed its present formation of a generally wide, sandy beach between Allerton Great Hill and Atlantic Hill, which has prograded from 200 to 1000 feet in front of intervening remnants of drumlins. A study of shore line and offshore depth curve changes since 1847 indicates that the beach has remained relatively stable. This stability is further indicated by the apparent lack of transportation of beach drift along the shore. The analysis of surface materials at mean tide level showed that identical materials exist along the foreshore of the area. Hand probings in the study area showed that the beach material comprises 1.5 to 2.5 feet of sand overlying gravel. The material from which the beach was built is glacial till ranging from clay to boulder sizes. There are at present no major sources from which new materials are added to the beach.

45. The study area is adequately protected by sea-walls which are generally well back of the mean high water line. The only storm damage experienced by these walls has been due to improper drainage of backfill. Only minor storm damage has been experienced by roads and structures behind the walls. Some structures are built in front of the walls and are supported on wood piles. These structures have not

suffered serious storm damage.

46. The surface of Nantasket Beach was formerly sand on both foreshore and backshore areas. In recent years stones have appeared in backshore areas to make them generally unsatisfactory for recreational purposes. Local beach maintenance crews have leveled these stones and generally buried them in the sand. These stones constitute the only problem at Nantasket. The beach was constructed by the natural disposition of glacial till containing materials ranging from clay to boulders. The sources of these materials have been exhausted or cut off from the sea so that there is no great source of materials available for modern beach building. The stones, therefore, appearing on the beach are contained in the existing beach materials and are being brought to the surface by the re-working of these materials by the waves. The absence of littoral drift indicates that the stones do not generally move along the beach but remain in the area where they are uncovered. The stones are uncovered on the foreshore area, and are washed onto the backshore by the uprush of the continuous breaking surf. During great storms, the stones move along the beach and the heavy deposit of stones in front of the sea-wall at the south end of the beach is the result of northeast storms. The process of the re-working of existing beach materials cannot be controlled, and hence the accumulation of stone deposits in backshore areas cannot be prevented.

47. The stones can be dealt with only after they have been deposited on the backshore, and the problem thus resolves itself into one of local maintenance of a beach in a condition satisfactory for recreational purposes. The maintenance will be periodic, dependent upon the

extent and amount of stone deposit, and the time of year the deposits become undesirable. Nantasket Beach is naturally more stony during the winter than the summer, and it is probable that maintenance of the beach will be required each year just prior to the opening of the bathing season. The beach may be maintained in a satisfactory recreational condition by several methods; the method being used in each case will be dependent upon the density of stone deposits and the option of the local authority prosecuting the work. Where stone deposits are light the method presently employed by the cooperating agency will prove satisfactory. The stone deposits may be leveled off and covered with the existing sand. When heavier deposits occur, they may be physically removed and replaced by an equal volume of sand; they may be buried in trenches or pits dug in backshore areas; or they may be covered by artificial fill. In no case should the stone deposits be removed without replacement with an equal volume of materials. Where artificial fill is employed to cover the stones, the fill need be only in sufficient quantity to make the beach satisfactory for use during the season, as the re-working of materials will continue to leave stones on the backshore. The covering of the stones by natural sand accretion through sand trapping devices is not possible because of the lack of littoral drift.

48. The United States has no financial interest in the maintenance of Nantasket Beach as a property owner or as a participant in a plan of improvement of the beach. The cost of the maintenance work, therefore, must be entirely borne by local authorities. The Metropolitan District Commission has jurisdiction over the Nantasket Reservation and regularly employs forces to maintain the reservation.

49. Conclusions: It is concluded that:

a. Nantasket Beach is a stable beach on which there is no problem of erosion, or of damage to sea-walls. The establishment of a project for the prevention of erosion, the stabilization and improvement of the beach, and the protection of the sea-walls, therefore, is not required.

b. The beach is adequate for recreational purposes but suffers through the collection of stones in backshore areas. These stones are the result of the re-working of existing beach materials, and their accumulation cannot be prevented by the erection of any type of shore protection works. The correction of beach conditions to provide suitable recreation areas is a problem of periodic beach maintenance by the local authorities. The maintenance may be accomplished by several methods.

(1) Covering the stones with existing sand.

(2) Burying stones in trenches or pits dug in the backshore.

(3) Removing stone deposits and replacing with equal volumes of suitable sand.

(4) Covering the stones with artificial fill.

The method to be employed is dependent in each case upon the beach conditions encountered and the decision of the local authority.

c. The maintenance of the beach as a suitable recreational area is justified by the public investment of $2,055,000 in the reservation and the private investments of $1,077,420 in the adjacent area, which investments have developed Nantasket as the principal resort south of Boston.

d. No share of the expense of the maintenance of the beach should be borne by the United States.

50. Recommendation: - It is recommended that the cooperating agency continue maintaining the beach in a suitable condition for recreational use, expanding its maintenance methods as necessary to bury and cover the stone deposits more completely or to remove the stones and replace them with equal volumes of sand.

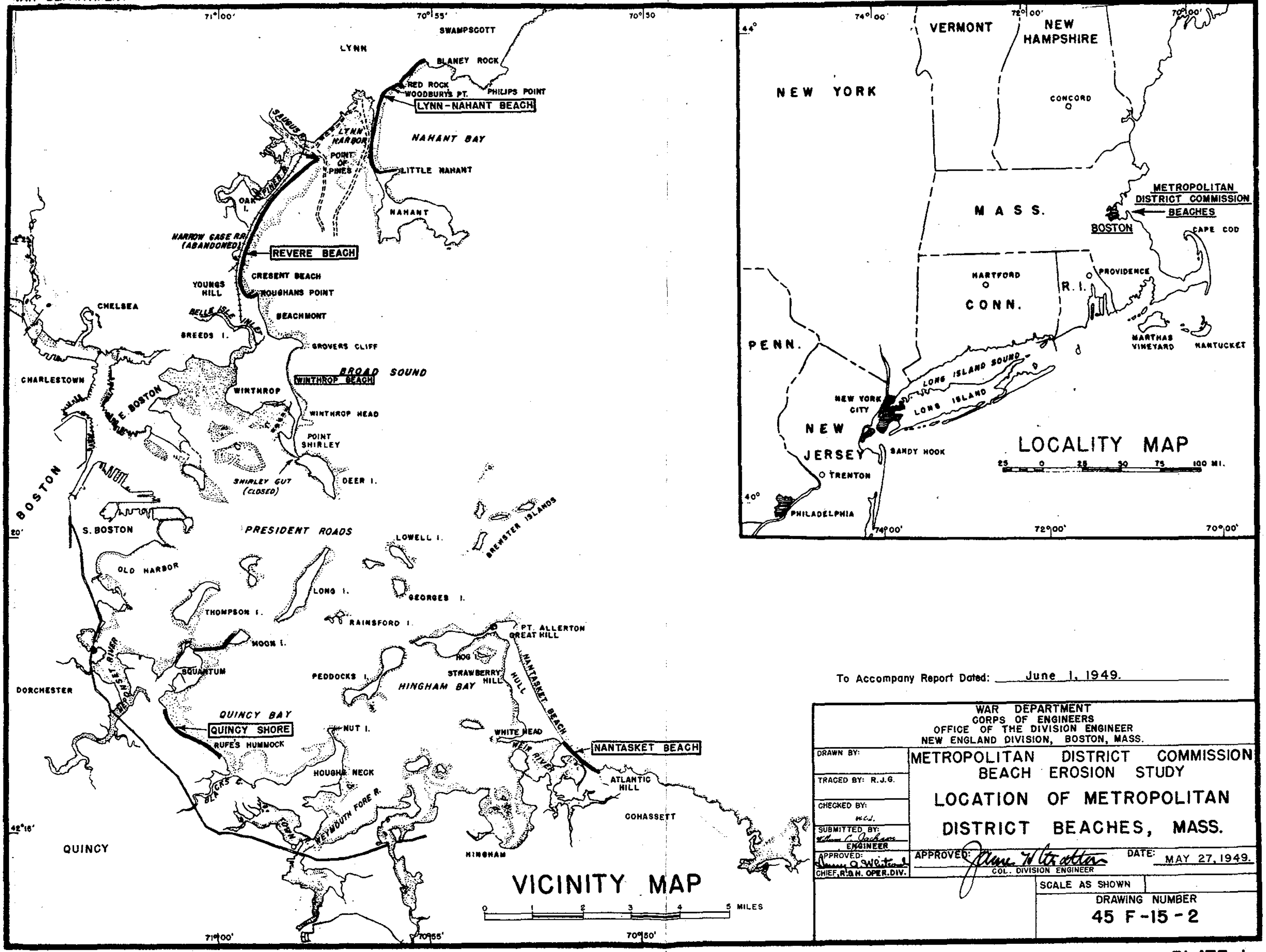
JAMES H. STRATTON
Colonel, Corps of Engineers
Division Engineer

7 Inclosures

4 Plates
3 Figures

WAR DEPARTMENT

CORPS OF ENGINEERS U. S. ARMY



To Accompany Report Dated: June 1, 1949.

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY:

TRACED BY: R.J.G.

CHECKED BY: w.c.j.

SUBMITTED BY: Jackson
ENGINEER

APPROVED:
CHIEF, R.&H. OPER. DIV.

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

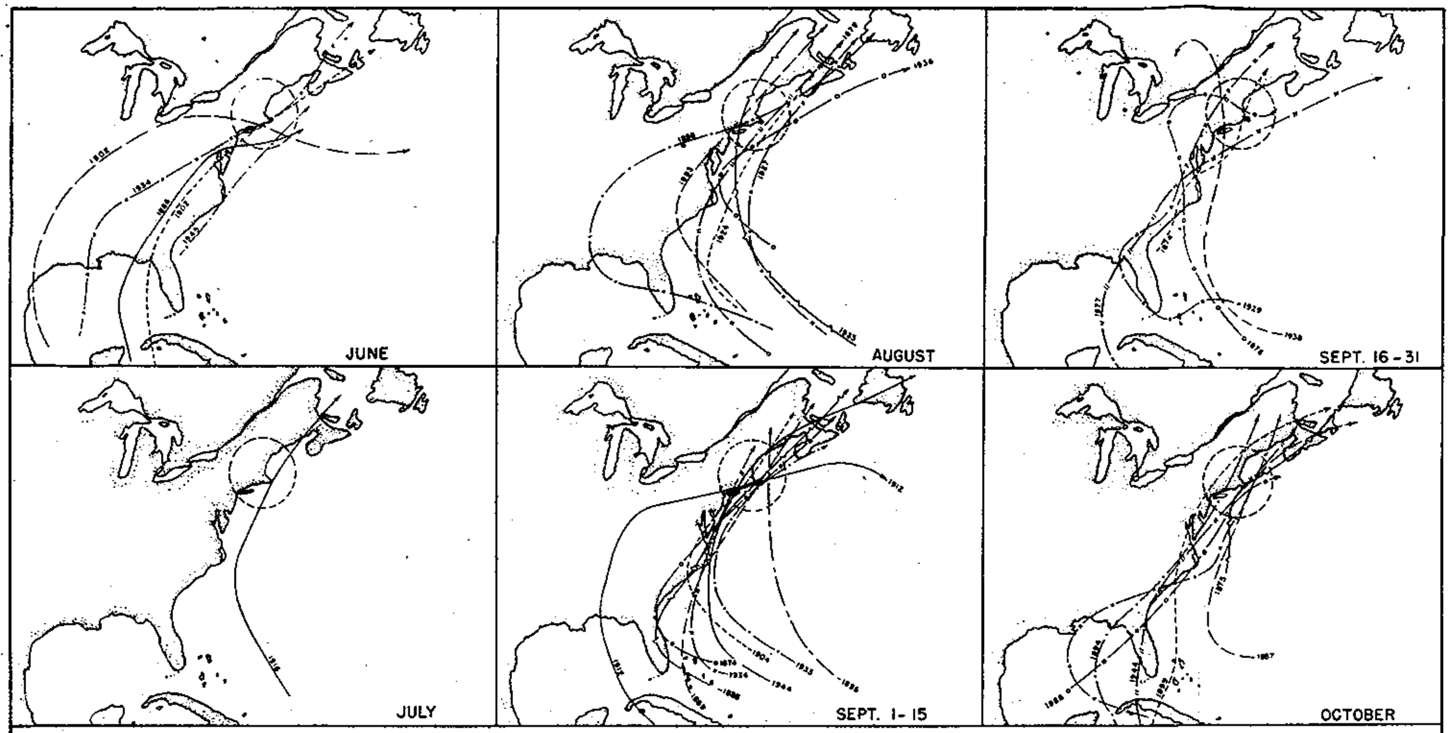
LOCATION OF METROPOLITAN DISTRICT BEACHES, MASS.

APPROVED: James H. Stratton
COL. DIVISION ENGINEER

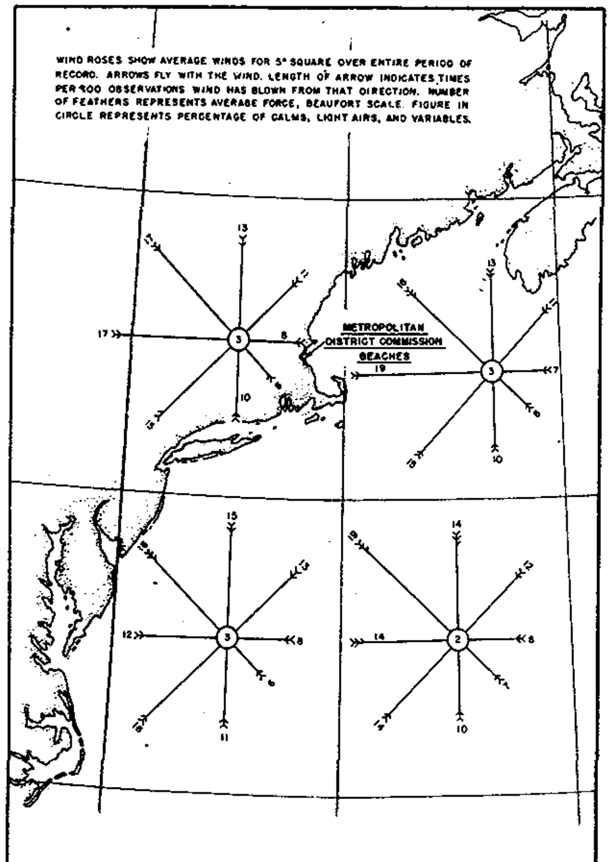
DATE: MAY 27, 1949.

SCALE AS SHOWN

DRAWING NUMBER
45 F-15-2

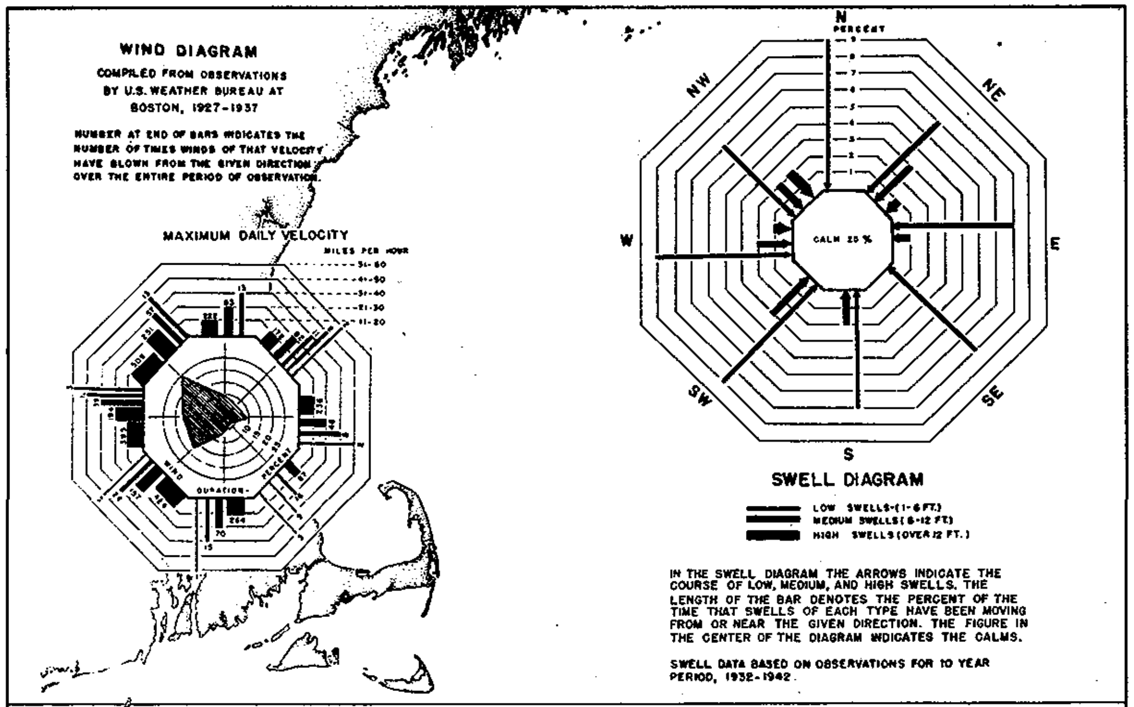


PATHS OF TROPICAL STORMS OF HURRICANE INTENSITY



WIND ROSES SHOW AVERAGE WINDS FOR 5° SQUARE OVER ENTIRE PERIOD OF RECORD. ARROWS FLY WITH THE WIND. LENGTH OF ARROW INDICATES TIMES PER 100 OBSERVATIONS WIND HAS BLOWN FROM THAT DIRECTION. NUMBER OF FEATHERS REPRESENTS AVERAGE FORCE, BEAUFORT SCALE. FIGURE IN CIRCLE REPRESENTS PERCENTAGE OF CALMS, LIGHT AIRS, AND VARIABLES.

PREVAILING WINDS



WIND DIAGRAM

COMPILED FROM OBSERVATIONS
BY U.S. WEATHER BUREAU AT
BOSTON, 1927-1937

NUMBER AT END OF BARS INDICATES THE NUMBER OF TIMES WINDS OF THAT VELOCITY HAVE BLOWN FROM THE GIVEN DIRECTION OVER THE ENTIRE PERIOD OF OBSERVATION.

SWELL DIAGRAM

- LOW SWELLS-(1-6 FT.)
- MEDIUM SWELLS (6-12 FT.)
- HIGH SWELLS (OVER 12 FT.)

IN THE SWELL DIAGRAM THE ARROWS INDICATE THE COURSE OF LOW, MEDIUM, AND HIGH SWELLS. THE LENGTH OF THE BAR DENOTES THE PERCENT OF THE TIME THAT SWELLS OF EACH TYPE HAVE BEEN MOVING FROM OR NEAR THE GIVEN DIRECTION. THE FIGURE IN THE CENTER OF THE DIAGRAM INDICATES THE CALMS.

SWELL DATA BASED ON OBSERVATIONS FOR 10 YEAR PERIOD, 1932-1942.

WIND AND SWELL DIAGRAMS

To Accompany Report Dated: June 1, 1949.

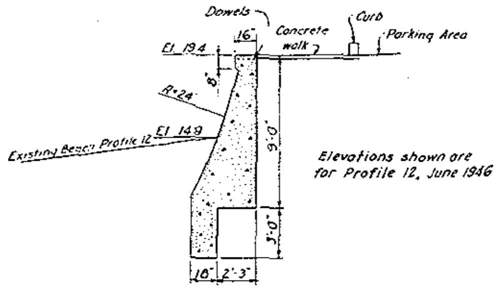
WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY
TRACED BY: R.J.G.
CHECKED BY
SUBMITTED BY
ENGINEER
APPROVED:
CHIEF, ENGR. OPERATIONS DIV

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

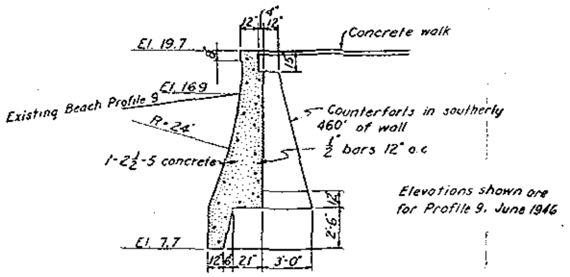
WIND AND SWELL DIAGRAMS
HURRICANES AND PREVAILING WINDS

APPROVED James H Stratton
COL. DIVISION ENGINEER
DATE MAY 27, 1949.
SCALE AS SHOWN
DRAWING NUMBER
46-F-15-2



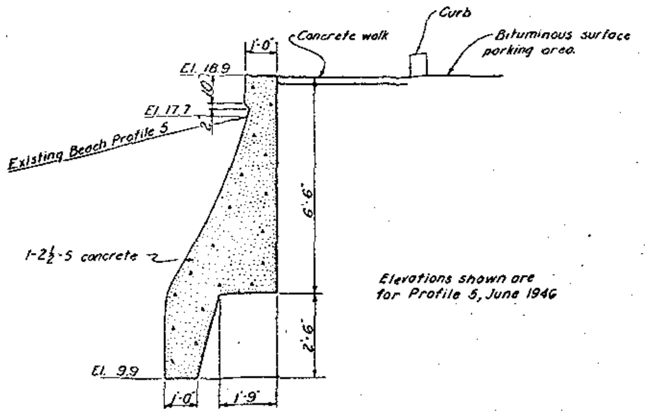
SEA WALL AT NORTH PARKING AREA
(PROFILES 11-14)

12" 0 5' 10'
SCALE: $\frac{1}{4}$ INCH = 1 FOOT


12"
4"
12"
Concrete walk
El. 19.7
8"
15"
Existing Beach Profile 9
El. 16.9
R=24'
Counterforts in southerly 460' of wall
$\frac{1}{2}$" bars 12" o.c
1-2$\frac{1}{2}$-5 concrete
1'2"
2'-6"
El. 7.7
12"
6"
21"
3'-0"
Elevations shown are for Profile 9, June 1946

SEA WALL AT M.D.C. BATH HOUSE
(PROFILES 9-10)

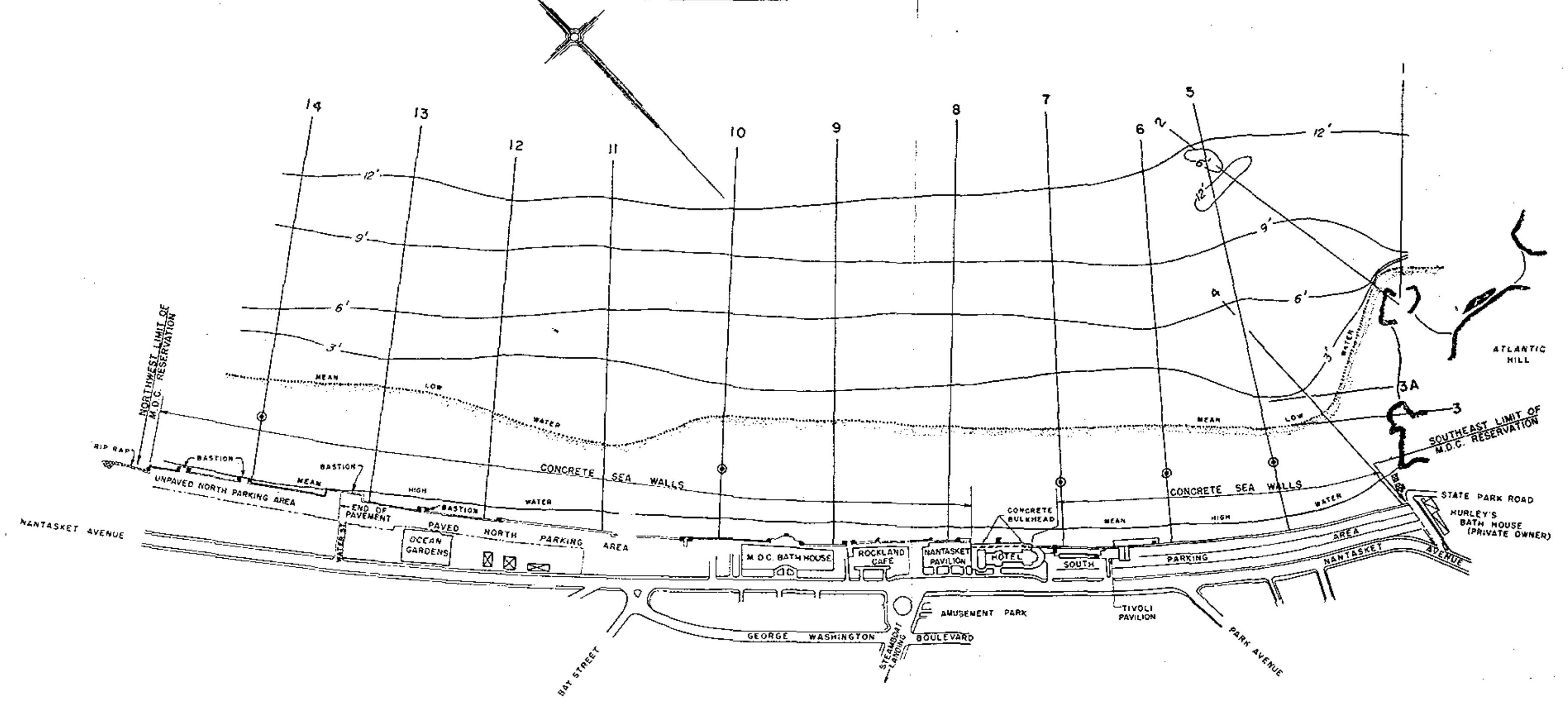
12" 0 5' 10'
SCALE: $\frac{1}{4}$ INCH = 1 FOOT


1'-0"
Concrete walk
Curb
Bituminous surface parking area.
El. 18.9
El. 17.7
Existing Beach Profile 5
6'-6"
1-2$\frac{1}{2}$-5 concrete
Elevations shown are for Profile 5, June 1946
2'-6"
El. 9.9
1'-0"
1'-9"

SEA WALL AT SOUTH PARKING AREA
(PROFILES 4-7)

12" 0 1' 2' 3' 4' 5'
SCALE: $\frac{1}{2}$ INCH = 1 FOOT

TYPICAL SECTIONS OF EXISTING WALLS



PLAN

100' 0 200' 400' 600'
SCALE IN FEET

NOTES

Shore lines and offshore depth curves are from a survey by the Corps of Engineers, June 1946.

Profile locations are indicated by lines numbered from 1 to 14. Length of line indicates length of profile.

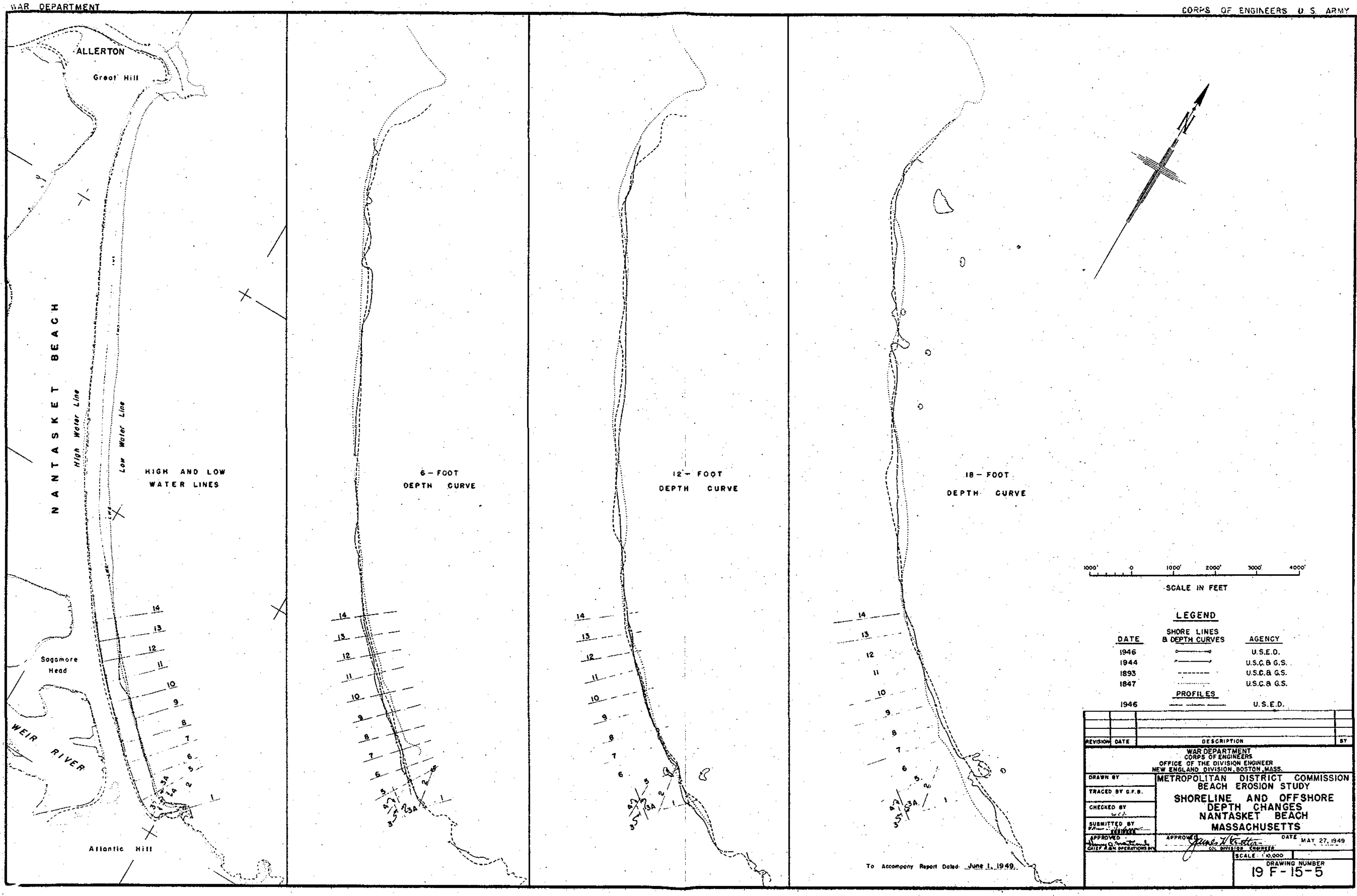
Locations of points at which beach samples were taken and hand probings made indicated by ◉. Samples taken only at Profiles 5,7 and 14.

To Accompany Report Dated: June 1, 1949.

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY P.D.M.	METROPOLITAN DISTRICT COMMISSION BEACH EROSION STUDY
TRACED BY P.D.M.	**EXISTING STRUCTURES**
CHECKED BY W.F.J.	**NANTASKET BEACH** **MASSACHUSETTS**
SUBMITTED BY ENGINEER	
APPROVED CHIEF, R&R OPERATIONS DIV.	APPROVED James H. Stratton COL. DIVISION ENGINEER DATE MAY 27, 1949.
	SCALE: AS SHOWN
	DRAWING NUMBER 18 F-15-5

PLATE D-1



To Accompany Report Dated June 1, 1949.

LEGEND

DATE	SHORE LINES & DEPTH CURVES	AGENCY
1946	o———o	U.S.E.D.
1944	————	U.S.C.& G.S.
1893	- - - - - - -	U.S.C.& G.S.
1847	··············	U.S.C.& G.S.
	PROFILES	
1946	—— —— ——	U.S.E.D.

REVISION	DATE	DESCRIPTION	BY

WAR DEPARTMENT
CORPS OF ENGINEERS
OFFICE OF THE DIVISION ENGINEER
NEW ENGLAND DIVISION, BOSTON, MASS.

DRAWN BY
TRACED BY G.F.B.
CHECKED BY W.C.J.
SUBMITTED BY
APPROVED
CHIEF R.&H. OPERATIONS DIV.

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

SHORELINE AND OFFSHORE DEPTH CHANGES NANTASKET BEACH MASSACHUSETTS

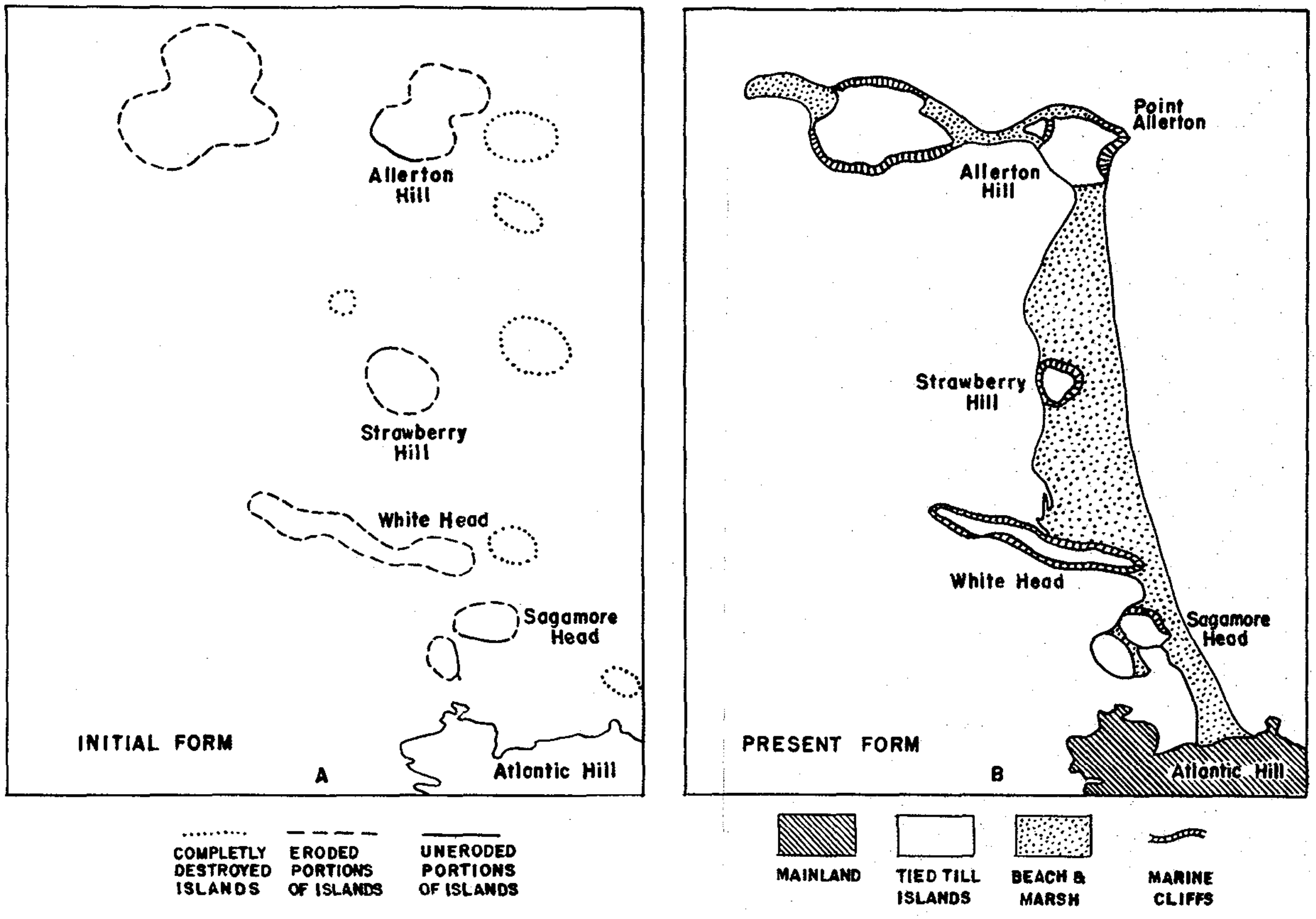
APPROVED James H Stratton
COL. DIVISION ENGINEER

DATE MAY 27, 1949

SCALE: 1:10,000

DRAWING NUMBER
19 F-15-5

PLATE D–2



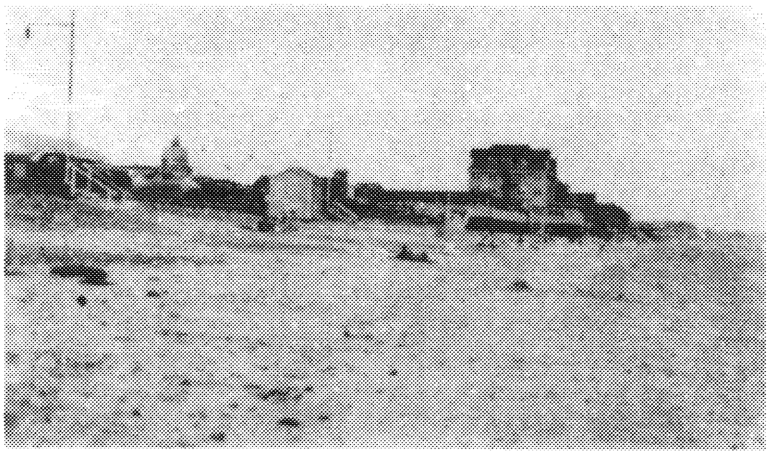
INITIAL AND PRESENT FORM OF NANTASKET BEACH. (AFTER JOHNSON, REED, LAFORGE)

METROPOLITAN DISTRICT COMMISSION
BEACH EROSION STUDY

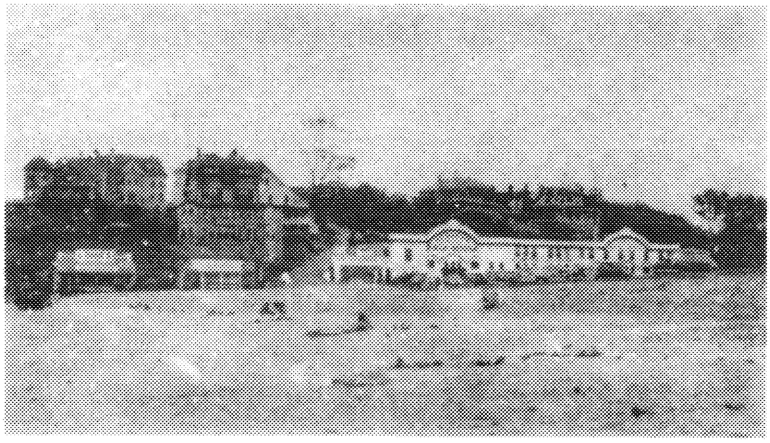
NANTASKET BEACH, MASS.

GEOLOGICAL DEVELOPEMENT

FIG. D-1

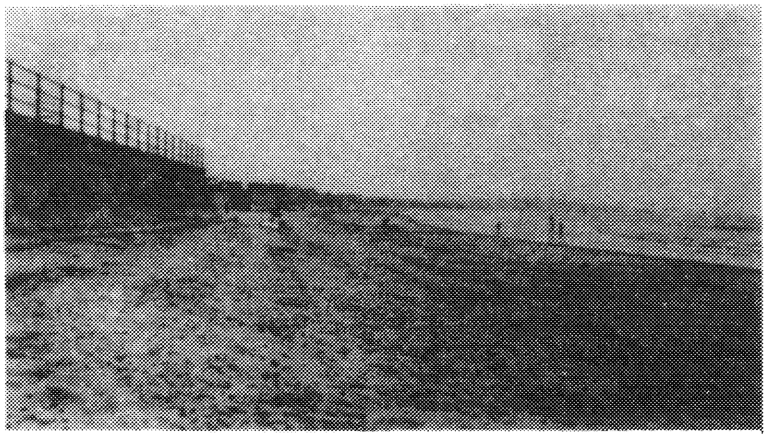


Looking northwest from Profile 5, showing beach after stones on backshore had been covered with sand by power graders.

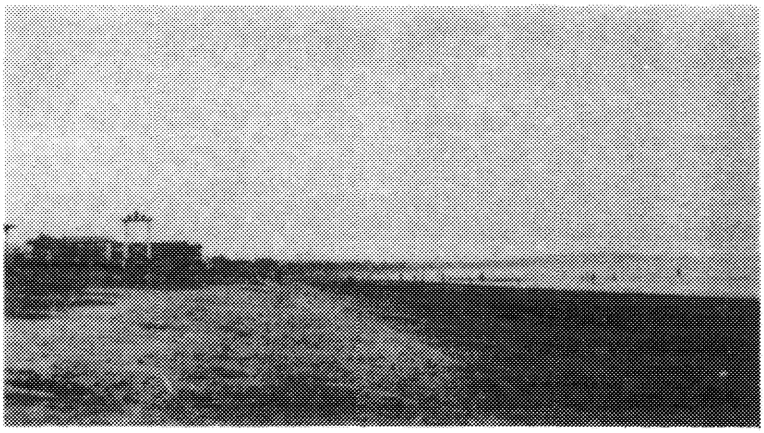


Looking southeast from Profile 5, showing natural stone ridge on backshore.

Metropolitan District Commission Study
BEACH CONDITIONS
NANTASKET BEACH, MASS.
Fig. D-2



Looking northeast from Profile 13. Beach elevations at wall have built up about 12 inches in 6 months.



Looking northwest from Profile 9, showing beach in front of bathhouse after stones on backshore had been leveled by power graders.

Metropolitan District Commission Study
BEACH CONDITIONS
NANTASKET BEACH, MASS.
Fig. D-3

CORRECTED PAGES TO BE INSERTED IN THIS REPORT

	N
Page No.	4
" "	22